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Lockheed Aircraft Corporation

ADVANCED DEVELOPMENT PROJECTS
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MODEL U-2R

TITLE PROPOSAL FOR U-2R AIRPLANE

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SUMMARY

This report presents a proposal for a much improved version of the U-2 airplane. The essential aerodynamic characteristics and economical operating costs of the present airplane are retained. The internal volume available for equipment has been increased by 77 $ft.^3$, which allows all the equipment currently stored externally to be located inside. The internal arrangement provides the maximum flexibility of payload selection, and will allow a wide variety of missions to be flown with the minimum time required for equipment changes.

The wing area is increased to 1,000 $ft.^2$ to allow optimum utilization of the improved and higher thrust J75P-13B engine. The U-2 aspect ratio and wing thickness ratios are retained and the tail size is increased to provide the required stability and control characteristics. The all moveable horizontal stabilizer provides a significant increase in the allowable center of gravity travel, thus eliminating ballast in all but the most extreme loading conditions.

Performance of the U-2R airplane extends by large margins the capabilities of the existing airplanes. The design condition is a 4,000 mile mission at maximum

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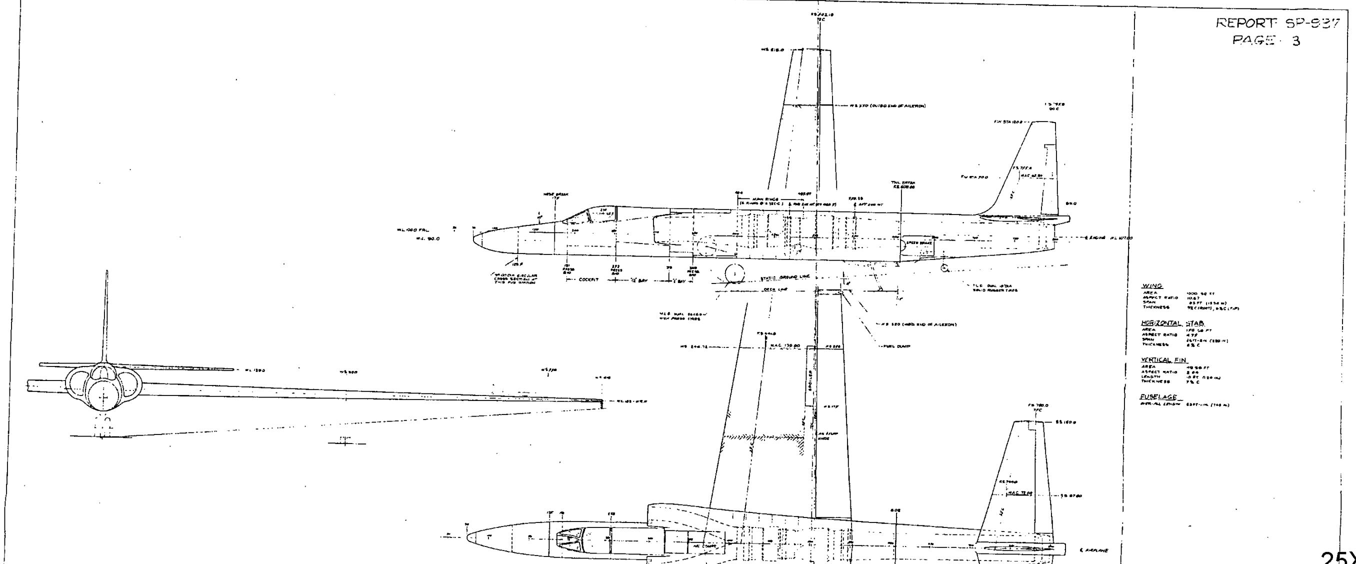
altitude, the climbing cruise starts at 68,000 feet and ends at [redacted] 25X1
This mission requires 12,730 pounds of fuel. With full internal fuel capacity of 19,350 pounds available in an overload condition, an unrefueled maximum
25X1 range of [redacted] is achieved. Compared with the U-2C, these figures represent an increased maximum range capability of [redacted] and 25X1
a maximum altitude increase of [redacted] for a comparable range maximum altitude mission. 25X1

The U-2R is equipped for carrier operation. Provisions for the arresting hook are included in the basic structure. A landing gear system with the required strength capability and wing spoilers is provided. The outer wing panels are hinged and manually folded to provide more convenient handling on the ship's elevator. Performance of the carrier version is virtually the same as that for the basic airplane, being changed only by installing the arresting hook and hook fairing.



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GENERAL ARRANGEMENT U-2R

FIG. 1

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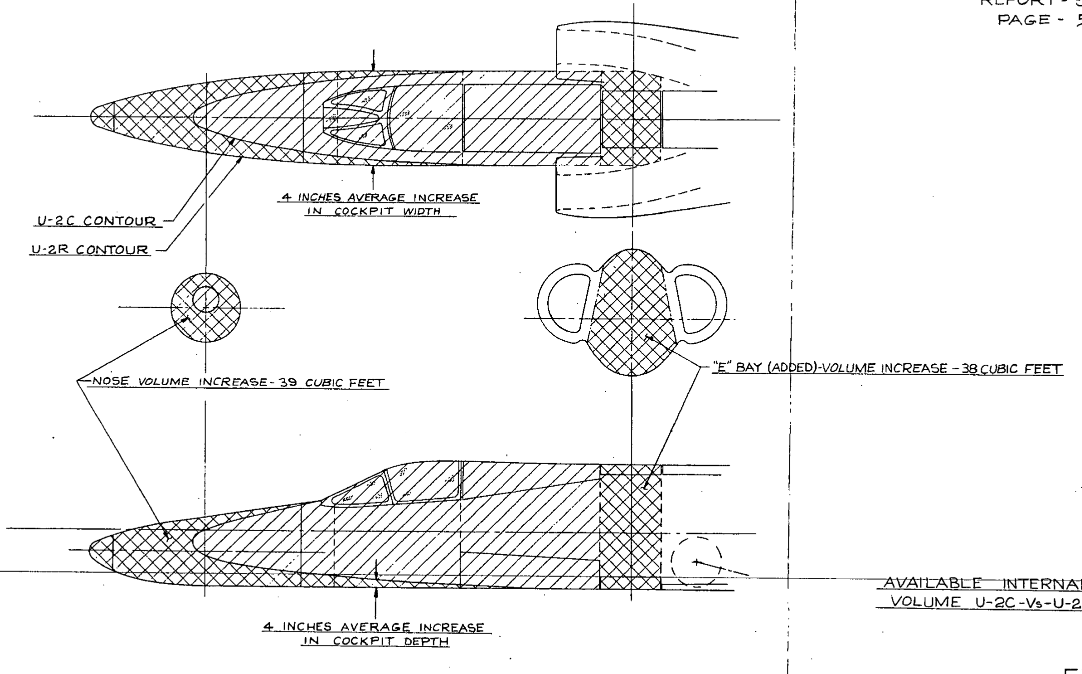

AVAILABLE INTERNAL VOLUME U-2C-Vs-U-2R

FIG. 3

INTRODUCTION

Mission requirements of the present U-2 airplanes point out the desirability of increasing the volume available for equipment stowage and at the same time increase the range and altitude capability of the airplane. Studies have been conducted, and reported in previous proposals, that have satisfactorily resolved the equipment stowage problem. However, these proposals which retained the existing wing planform produced only minor improvements in airplane performance and were therefore not completely acceptable. This report describes a further extension of this effort and represents the optimum altitude-range configuration for an airplane powered by a single P&W J75P-13B engine.

To achieve improvements in altitude and range performance, improved lifting characteristics are needed. A short review of investigations into the general altitude improvement problem is given in this report. The result of this and previous efforts is the proposed U-2R. The improved performance of this design are illustrated by altitude and range characteristics for representative missions.

The U-2R configuration retains the 30 inches of added equipment bay and the longer nose of previous proposals. The nose section forward of FS 175 is attached to the fuselage by four quick release fasteners; this allows the best possible servicing environment and permits payload changes to be made in the shortest possible time. The Q-bay aft of the cockpit is accessible on the top and bottom, unchanged from existing airplanes. The variations in mission equipment that can be fitted into this configuration are shown on pages 30 thru 40. This shows that the flexibility of the present airplanes has been considerably extended, and the U-2R configuration offers capability for a wider range of data gathering missions.

Review of Altitude Improvement Problem

To achieve increases in altitude performance for the U-2 without weight reduction requires a wing change. The lifting potential of the present 600 square foot wing was fully realized with the installation of the J75 engine in the U-2C. The U-2C maximum power cruise is at $C_L = 1.0$.

An increase in thrust such as changing from the J75P-13A to the J75P-13B drives the airplane into either stall or Mach buffet. This situation is apparent when the U-2C cruise condition is shown on an altitude vs. Mach number plot along with the stall and Mach buffet lines. Figure 4 shows this for an airplane gross weight of 20,000 pounds. The situation is essentially the same for other weights where the buffet lines and cruise points move up in altitude for lighter weights and down for heavier weights.

25X1

Increasing the lifting capability for the U-2 results from increasing lift coefficient, Mach number, or wing area. Investigations have been made in all three of the above approaches. Increasing wing area is the most successful, since the present airfoil and wing characteristics are very good.

The present U-2 airfoil, 63A409 root - 63A406 tip, achieves performance worthy of notice. At the U-2C cruise conditions, $M \hat{=} .69$ and $C_L \hat{=} 1.0$, 40% of the top surface of the wing is supersonic with no significant shock losses during the compression back to subsonic flow. An equally important feature, associated with the U-2C's altitude, is that the Reynold's number is low enough, 2.5×10^6, to allow laminar flow over a large percentage of the wing in its normal roughness condition. The so-called laminar flow characteristics of this airfoil are being realized. It is interesting to note that the maintenance of laminar flow on the upper surface up to $C_{L's}$ of 1.0 results from that region going supersonic and eliminating the adverse pressure gradient that would exist subsonically at high $C_{L's}$.

Some development work was done utilizing the supercritical airfoil concepts being developed by [redacted] Success was attained in delaying drag rise to $M = 0.8$ at $C_L = 0.8$ for a complete wing. On this airfoil, 85% of the top surface is supersonic. The primary fault of this airfoil was its high profile drag.

25X1

The higher profile drag in combination with higher wing and tail weight more than offsets the advantage of high Mach number, leaving the altitude performance inferior to the U-2C.

Investigations to increase Mach number capability by reduced thickness or sweep of the wing have shown little or no promise because of the structural weight increases. The potential for increased weight or altitude from higher Mach number is small unless shock losses will be accepted. Inherent in increasing Mach number without shock loss is reduced negative pressure co-efficients, which means reduced upper surface lift.

Simply increasing wing area at the same span was not successful in improving altitude performance. The added wing weight and friction drag negated a slight increase in Mach number. Additional span was necessary to reduce drag due to lift. A review of change in airplane weight with increased span showed considerable span could be added with a reducing drag due to lift.

The necessary compromises were evaluated and it was found that a 1,000 square foot wing with the original U-2 planform was a close optimum for the new higher thrust J75P-13B engine and payload requirements. More span and area would increase altitude capability slightly, however, the many increasing problems of size are against it.

MISSION PERFORMANCE

The increase in wing area together with improvements in general arrangement, equipment, etc. gives a Zero Fuel Weight of 17,400 pounds. The net effect of the increased weight on performing various missions is the final criteria of value. The better match of engine thrust, wing area and wing span and the increase in wing fuel volume have yielded significant improvements in both altitude and range. The following paragraphs will discuss the basis for performance calculations, the ground rules used in putting together missions, and representative missions which portray the U-2R capabilities.

Performance Basis

The U-2R performance is built on U-2C flight test data and supplemented with U-2 wind tunnel data and analysis. Recent U-2C field data has been analyzed and found to agree with original U-2C flight test data when increased weight, engine pressure ratio limits, and free air temperatures are accounted for. Normal analytical methods are used to recognize the configuration differences between the U-2R and U-2C.

The engine data used in this report are based on altitude tests of a J75P-13B engine; these tests were conducted during August and September 1965, at N.A.T.T.S., Trenton, New Jersey. Recent flight data with the same instrumented engine in a U-2G are in agreement with these previous test data. A full set of data on the engine is not yet available, however, what has been made available is sufficient to calculate reasonably good cruise performance. Climb and descent performance is less well defined, but for the U-2R this has a relatively small effect on range.

The mission performance presented in this report is a straightforward estimate of what the U-2R will achieve. The take-off, descent and reserve allowances are based on U-2C experience. The 1956 ARDC Model Atmosphere is used.

Since the U-2R cruises at lower lift coefficients, the maximum altitude mission cruise is at [redacted] This compares with the [redacted] altitude cruise of the U-2C. For maximum range the U-2R cruises at [redacted]

25X1

Partial Fuel Missions

Two maximum altitude missions with partial fuel load, 3,000 N.M. and [redacted] are presented in Figure 5. They show the improved altitude

25X1

25X1

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capability as compared with present U-2C's. The comparison is shown as altitude versus range. For a range of 3,000 N.M., comparable to a maximum altitude maximum range U-2C mission with slipper tanks, the start of cruise altitude is [redacted] This is an altitude advantage of approximately [redacted] Even the [redacted] mission which starts cruise at over 68,000 feet and ends at [redacted] has an altitude advantage. 25X1 25X1 25X1

The take-off gross weights for these two U-2R missions are 26,790 and 30,130 pounds. The times from take-off to end of cruise are 7.1 hours and 9.6 hours.

<u>Maximum Fuel Load Missions</u>

Two maximum fuel missions illustrate the extreme performance capability resulting from the large increase in fuel volume of the 1,000 square foot wing. One mission is flown at maximum altitude all the way and the other is flown at the altitude for best range. Figure 6 shows that starting cruise at a maximum altitude of over 64,000 feet and ending at [redacted] the U-2R achieves a range 25X1
25X1 of [redacted] Flying at best range altitude which starts at over 55,000 feet and ends at 69,000 feet, the U-2R achieves a range of [redacted] Both missions take-off at 36,750 pounds. The flight times get rather long, being 13.6 hours to end of cruise for the maximum altitude mission and 17.1 hours 25X1

25X1

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to the end of cruise for the best range mission.

Mid-Mission Penetration

A composite radius mission is shown which reduces the requirement for aerial refueling. A 3,000 N.M. (1,500 N.M. penetration radius), segment at maximum altitude is assumed with a best range cruise from and back to the base. Figure 7 shows that with maximum fuel the U-2R can start penetration 25X1
25X1 [redacted] from his base at almost 67,000 feet, cruise in and out [redacted]
25X1 ending penetration at [redacted] and cruise [redacted] back to his base. For 25X1
missions such as this, the initial penetration altitude can be higher the closer the base is to the penetration point by carrying less fuel at take-off. It is interesting to note that the U-2R reaches out over [redacted] from its base 25X1
and returns. It also spends over half of the penetration time [redacted] 25X1

General Comments

The 1,000 square foot wing and J75P-13B engine can give significant altitude and range improvements as well as general arrangement improvements.

The handling qualities during high altitude cruise and cruise control will be greatly improved over the U-2C since it is not flying in the stall-Mach buffet corner.

The U-2R will accept up to 50% more thrust before it is limited by both stall and Mach buffet as is the U-2C.

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DESCRIPTION

A general arrangement drawing of the U-2R airplane is shown on Figure 1. The installation of the payload and ship's equipment included in this proposal is illustrated on the Inboard Profile, Figure 2. The basic airplane systems are: [redacted] The payload comprises: 25X1

B Overload with System VI	655 Lbs.
System 9B	60 "
System 12B	34 "
System 13A	176 "
Oscar Sierra	20 "
Total	945 LBS.

Alternate payload arrangements in the nose and Q-bay are shown on pages 30-39. These include equipment packages carried in the SR-71, and two place versions

25X1 of [redacted] 25X1

The fuselage nose is sized by the requirements of the [redacted] A forebody arrangement with the Q-bay modified to provide a cockpit for the observer

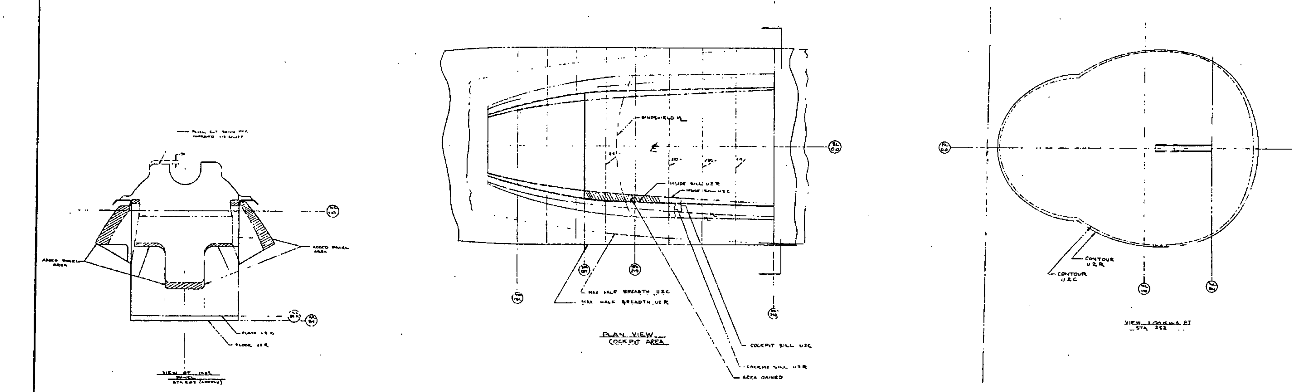
25X1 and the [redacted] in the nose is shown on Figure 8. This same nose size is

FORM 57674.2

retained for all versions and is attached to the fuselage by four quick release latches. This feature adds to airplane flexibility since it allows the nose systems to be changed in the same manner as is currently used with the various Q-bay hatch packages. The available volume in the nose is increased by 39 $ft.^3$ and the volume added by the 30 inch equipment bay from FS 319 to FS 349 adds 38 $ft.^3$, giving a total internal volume increase of 77 $ft.^3$ In addition, the cockpit width is increased by 4 inches and the cockpit floor lowered 2 inches while maintaining the same waterlines for the canopy. These changes should alleviate the instrument installation space problems and improve crew confort and efficiency. A comparison of the new and old instrument panels is shown in Figures 9 and 10.

Attention has been given in the fuselage design to providing easier engine removal. The aft fuselage break has been moved forward of the dive brakes, the fuselage section forward of the break, through which the engine has to pass, is slightly larger and the structure in this area has been rearranged to give the maximum clearance.

The wing has an area of 1,000 $ft.^2$ with an aspect ratio of 10.67, the same as the present U-2. By holding the same aspect ratio, thickness/chord ratios and airfoil sections as the present wing, the development risk for this new model is quite low. New airfoil sections have been investigated and aspect ratio changes



COCKPIT SPACE COMPARISON

FIG. 9

considered in an attempt to obtain higher altitudes and greater range. None of these configurations produced any greater over-all efficiency than the present U-2 wing geometry has demonstrated over years of flight.

The wing structure is conventional with the box beam from 15% chord to 65% chord. Box beam skin panels carrying the wing bending and torsion loads shall be integrally stiffened with tee stiffeners. The integral wing fuel tank shall extend from the leading edge to the rear box beam (65% chord). A fuel tight rib at W.S. 135 shall divide the wing fuel into normal and overload conditions. This is discussed in the structural design section, page 25 . The trailing edge arrangement of flaps, ailerons and spoilers retains the essential features of the present U-2 wings. In order for the wing to fit on a carrier elevator a hinge is provided at W.S. 550 and the wing outboard can be folded up out of the way. This folding portion is dry wing and has no control surfaces.

The horizontal tail position is unchanged and is geometrically similar to the U-2 with the area increased to 150 $ft.^2$ to provide satisfactory stability level. The horizontal tail is all moveable for pitch trim with elevators for pitch control. This arrangement will provide much improved handling characteristics and will eliminate tail ballast requirements due to the extension of the allowable center of gravity travel between the forward and aft limits. The vertical tail is identical to to that on the present airplanes since this size gives a satisfactory level of directional stability.

Structural Design Criteria

The structural design criteria closely follows that of the present airplane. Design conditions are:

Gust Criteria - MIL Spec. 8860

V_L = 240 KEAS M = .80

V_H = 150 KEAS M = .75

Maneuver Conditions:

a) Normal Design Weight = 30,130

[redacted] 25X1

Load Factor = +2.5g

b) Overload Design Weight = 36,750
(Full Wing Fuel)

Load Factor = 2.0g

The wing strength level is based on load envelopes of the gust and normal design weight maneuver conditions. The Overload Design Weight load factor of 2 g is based on the strength capability as defined above. Wing fuel is divided into two tanks, normal and overload. Normal fuel is the 12,730 lbs. required for the 4,000 N.M. maximum altitude mission, the wing portion of this is contained

FORM 5767A.2

outboard of W.S. 135. The overload fuel fills in the wing inboard of W.S. 135 to the side of the fuselage and amounts to 6,620 lbs. Fuel tank sequencing uses the overload fuel first and then the normal fuel. It should be noted that the reduction in flight load factors for the overload condition applies only to the early part of the flight while the overload fuel is being used. With the overload tanks empty the normal maneuver load factor of 2.5g applies.

WEIGHT AND BALANCE

The U-2R weight estimate is based on preliminary load analyses of the structure and an evaluation of the functional equipment compared with present U-2 airplanes.

A breakdown of the weight estimate is shown on page 27a.

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	Lbs.
Wing	4,280
Tail	550
Fuselage	2,350
Landing Gear	560
Surface Controls	600
Propulsion Group	6,025
Instruments	100
Hydraulics	200
Electrics	525
Electronics	310
Furnishings	170
Air Conditioning	250
Tail Parachute	30
WEIGHT EMPTY	15,950
Pilot	285
O_2	80
Oil	40
Unusable Fuel	100
Payload	945
ZERO FUEL WEIGHT	17,400
Sump Fuel	750
Normal Wing Fuel	11,980
NORMAL TAKE-OFF WEIGHT	30,130
Overload Wing Fuel	6,620
OVERLOAD TAKE-OFF WEIGHT	36,750

FORM 5767A.2

The permissible total center of gravity travel for the U-2R is from 20% M.A.C. to 30% M.A.C. This permits a 5.5% M.A.C. range in allowable zero fuel center of gravity, and will allow a wide variety of payloads to be carried without the need of ballast. Figure 11 shows the center of gravity travel with the standard payload as previously defined. Also shown is the most forward loading that can be envisaged at this time, the [redacted] this is within 25X1 the permissible center of gravity range without ballast.

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CARRIER OPERATION

The U-2R airplane is designed for carrier operation.

The 103 foot wing span of the airplane is acceptable for the flight deck aspects of carrier operation. No problem of clearance with ship's structure exists while operating on the angled deck. Wing tip clearance with the island when the airplane is centered on the ship's center line is 10 feet or 25 feet, depending on the particular carrier used.

The outer wing panels are hinged at wing station 550 and manually folded to provide more convenient handling on the ship's elevator. Figure 22 is a diagram showing the U-2R in position on the standard 52 ft. x 70 ft. elevator.

Provisions for the arresting hook are provided in the basic airplane, including all necessary structure, hook controls, plumbing, etc.

A landing gear system with sufficient strength capabilities and proper force damping characteristics for carrier landings, and wing spoilers are provided as features of the basic airplane.

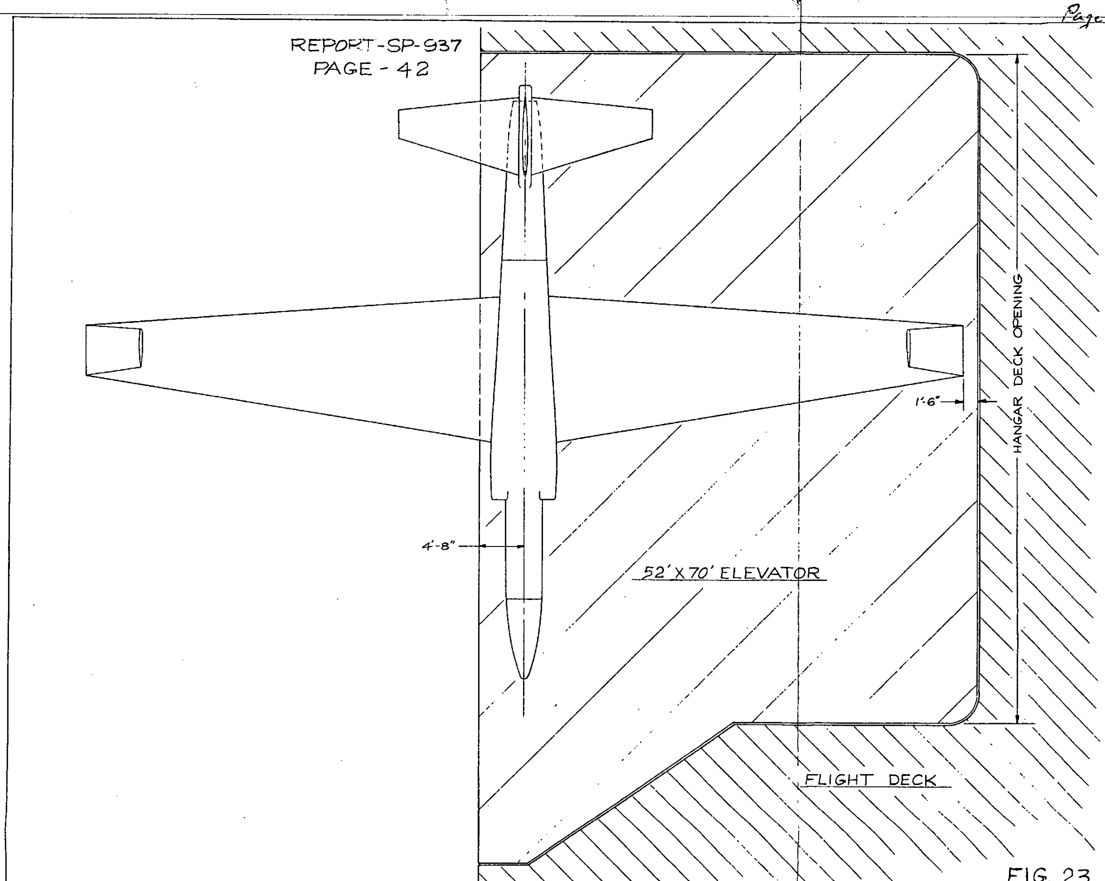

FIG. 23